



CSP Overview for BLM



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August 31, 2009

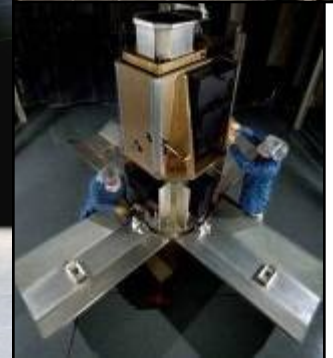
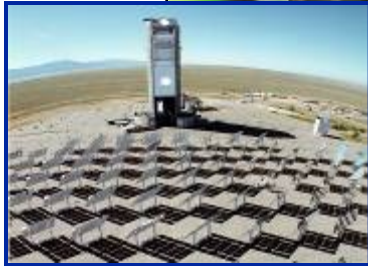


Four Mission Areas

SANDIA IS A NATIONAL SECURITY LABORATORY

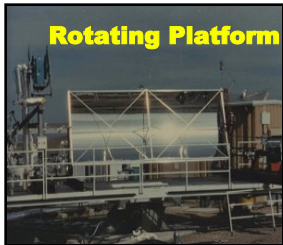
Missions: Sandia's missions meet national needs in four key areas:

- **Nuclear Weapons**
- **Defense Systems and Assessments**
- **Energy, Resources, and Nonproliferation**
- **Homeland Security and Defense**





Sandia's NSTTF



We provide:

- Built in 1976
- CSP R&D
- System and component testing
- Test and instrumentation design
- Test analysis and reporting
- Systems analysis and FMEA

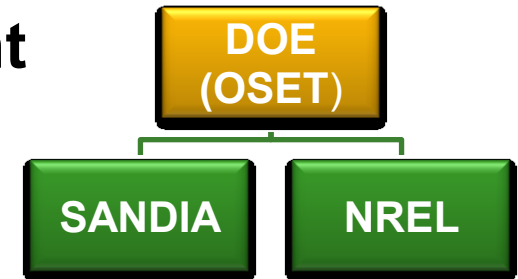
NATIONAL SOLAR THERMAL TEST FACILITY



SunLab's Role

SunLab is a virtual laboratory comprising the CSP Programs at Sandia National Laboratories (SNL) and the National Renewable Energy Laboratory (NREL). The Labs perform R&D on CSP components and systems

- **Advanced component development**
- **Systems Analysis**
- **Testing and evaluation**
- **Market Development Activities**
- **“Reality” brokers on the status of technologies**





Outline of Presentation

- **Types of technologies**
- **Overview of the CSP Technologies**
- **The Value of Thermal Storage**
- **Status of Technology Development**
- **Resource Availability and Energy Costs**
- **The DOE Program Focus**
- **Issues for BLM Consideration**



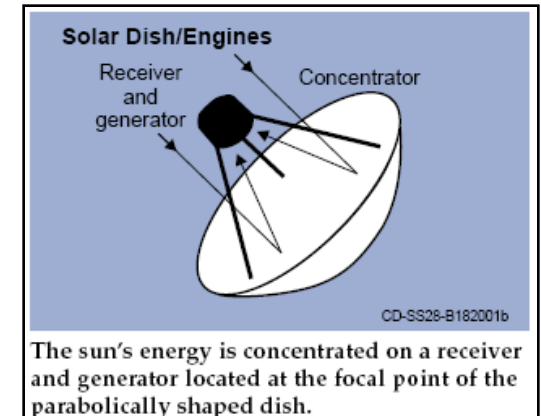
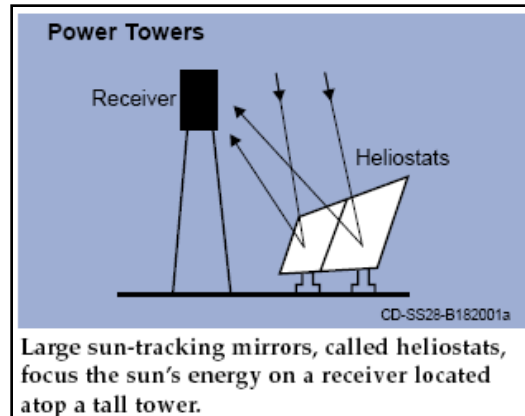
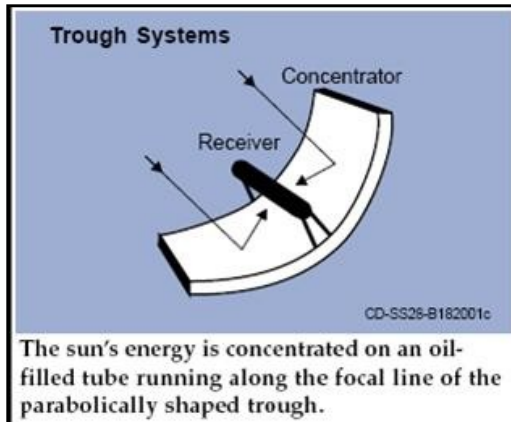
What can CSP do?



- Convert the sun's energy to heat and use that heat to power and engine/generator.
- Are utility-scale solar power (> 100 MW).
- Comprise three generic system architectures: line focus (trough and CLFR), point focus central (power tower), and point focus distributed (dish engine).
- More than 140 plant-years of commercial operation (10 plants, 400MW) in the Southwest.
- **Capable of providing dispatchable power for peaking and intermediate loads (storage or hybridization).**
- Mostly uses commodity items (turbines, glass, steel, aluminum, piping, controls, etc).



System Architecture



OPTICAL CONCENTRATION

Linear

- Parabolic 2-D shape
- Focal Length ~ 3m
- Tracks E to W
- CR ~ 30 to 40
- Fresnel reflector may be utilized

Point-Focus Central

- Parabolic 3-D shape
- Heliostats track in azimuth and elevation
- Focal Length ~ 100sm
- CR ~ 800

Point-Focus Distributed

- Parabolic 3-D shape
- Tracks on Sun in azimuth and elevation
- Focal Length ~ 4 m
- CR ~ 3000

DESCRIBE TRACKING AND AIMING



Parabolic Trough Technologies

SEGS (US 1985 – 1991) Nevada Solar One (US 2007) Andasol 1 (Spain 2009)



Nominal capacity: 354 MW
Constructed 1985 - 1991
9 Sites in California
Hybrid for dispatchability (25%)
Total reflec area > 2.3 Mill. m²
More than 117,000 HCEs
30 MW increment based on regulated power block size



Nominal capacity: 64 MW
Construction In 16 months
250 Acre solar field
30 minutes of TES
Capital invest: \$266 million
105% of planned performance
for the first 18 months of operation



Nominal Capacity: 44.9 MW
Two-Tank Molten-Salt Storage
7 full-load hours of storage
Capital Investment: 260 million €
549,380 m² of trough collectors



CLFR Designs

- **Continuous Linear Fresnel Reflector**
- **Approximates a line-focus trough collector**
- **May be lower cost because it doesn't use curved mirrors and places the reflectors near ground level -- reducing wind loads**





Power Tower Technologies

Solar Two Experiment (1995 – 1997) US



10 MW Capacity
Molten Salt WF/TES
Receiver η = 88%
 η of Storage > 98%
Dispatchability
demonstrated

PS 10 (2006) PS 20 (2009) Spain



11 MW & 20 MW Capacity
Once-through steam boiler
1 Hour TES (steam)
1878 helios (120 m² each)
Tower height 100m/ 160m
73 GWhr/annually

SEDC Demo (2008) IL



2 MW Capacity
**Direct Solar-to-
Steam**
High Temp. 550° C
Flat Glass Mirrors
Air Cooled
60 m receiver tower
1,641 helists (7 m²)

Sierra Demo (2009) US



**5 MW Demonstration
Plant (two towers)**
**46-MW Standard
module (16 towers)**
Small, flat mirrors
**Unique heliostat
control system**



Dish Stirling Technologies

**150 kW Demo
(2007) NM**



Utility-Scale Dish System
25 kW system
87 m² collector
Peak (net solar-to-electric)
efficiency 31.25%
4 cylinder KSE

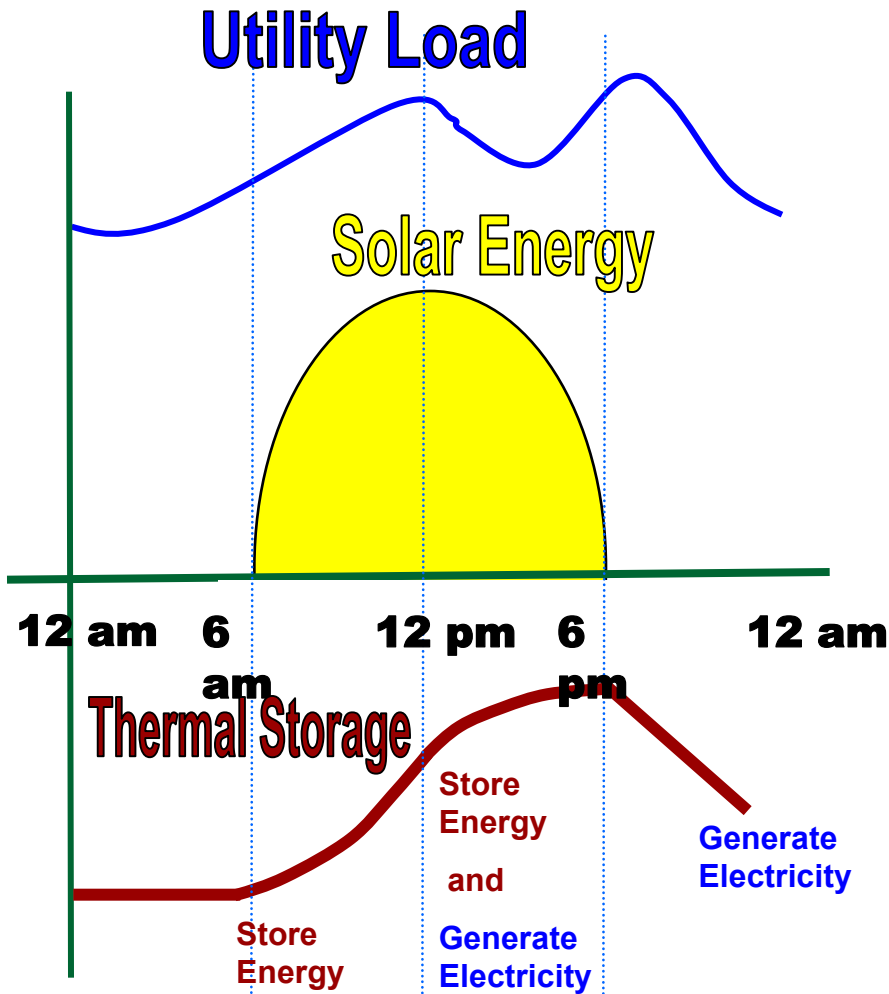
**90 kW Demo
(2009) Spain**



Utility/DG System
90 kW Capacity (1 MW)
3 kW systems
120/240 Volts AC
1 cylinder FPSE
Linear Alternator



The Value of Thermal Storage



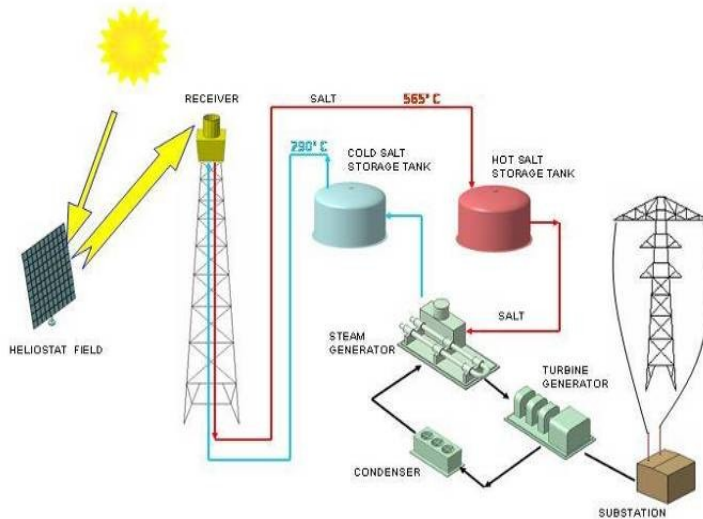
One operational scenario

THERMAL STORAGE

- **Decouples** solar energy collection and generation
- **Has high value** because power production can match utility needs
- **Is lower cost** because storage is cheaper than incremental turbine cost
- **Value of Thermal Storage is yet to be captured:**
 - carbon displacement value
 - capacity value for the utility
 - operational value to the ISO



Solar Two -- Molten-Salt



- 1500 tons ($\text{NaNO}_3/\text{KNO}_3$ 60/40 wt %)
- 107 MWhr thermal
- Operating T 290 C to 565 C
- Daily Efficiency of 98%
- Thermal loss from Hot Tank 4 C/day

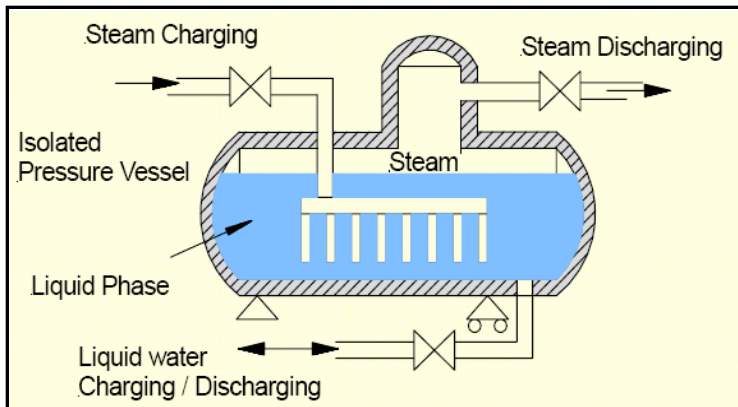
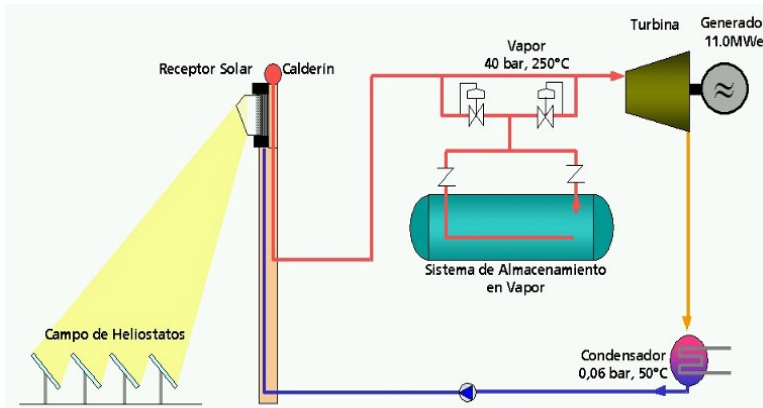




PS 10 -- Direct Steam Storage

For PS 20

- 4 sequentially operated tanks
- Charge at 250°C/40 bar steam
- Operates at 20 bar/50% turbine operation for 1 hour



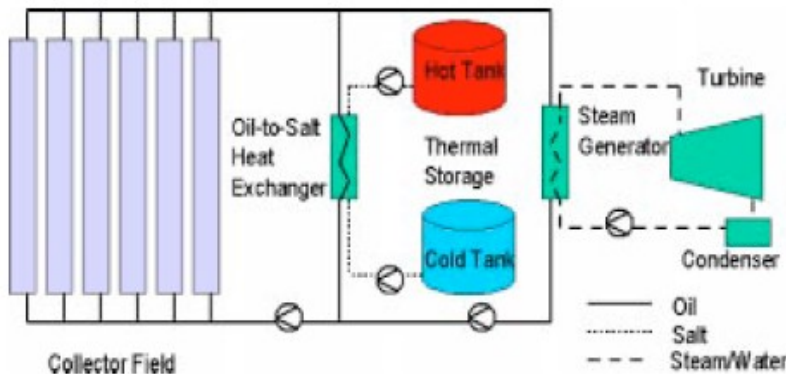


Andasol 1 MS Storage



2-Tank Molten Salt Storage

- 60% NaNO_3 and 40% KNO_3
- Melting Point of Fluid: 221 C
- Storage Capacity: 880 MWh
- Storage Tank Size: 13 m X 38 m
- 28 ,500 tons of salt
- Flow Rate: 948 kg/s
- Cold Tank Temperature: 292 C
- Hot Tank Temperature: 384 C





Status of CSP Technologies

- Trough systems are the most commercially mature of the CSP technologies.
- Dish Stirling systems are capable of the highest solar-to-electric efficiency of the three technologies.
- Molten-salt power towers most effectively integrate thermal storage into the operation of a CSP plant.
- There is no simple way to integrate thermal storage into a dish system.
- Trough systems are currently incorporating thermal storage in the form of two-tank MS systems.
- The power blocks in trough and power tower systems currently utilize wet cooling. Dish systems have captive radiators reducing water usage.



Technology Drivers

Near term:

- **to establish credible performance in order to secure project finance.**
- **to reduce cost of energy delivered.**
- **to establish and document O&M costs for CSP plants.**

Mid term: to establish reliable, cost effective energy storage that can be financed.

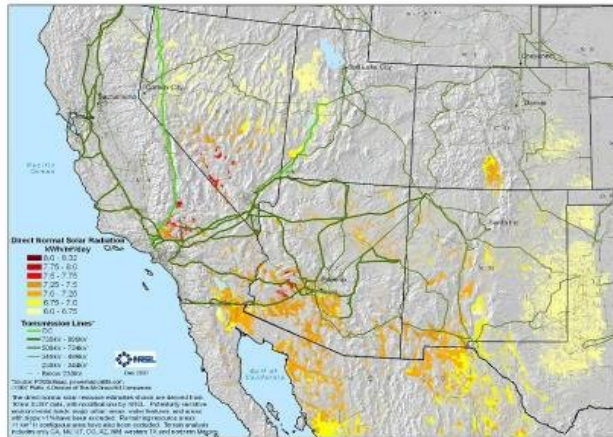
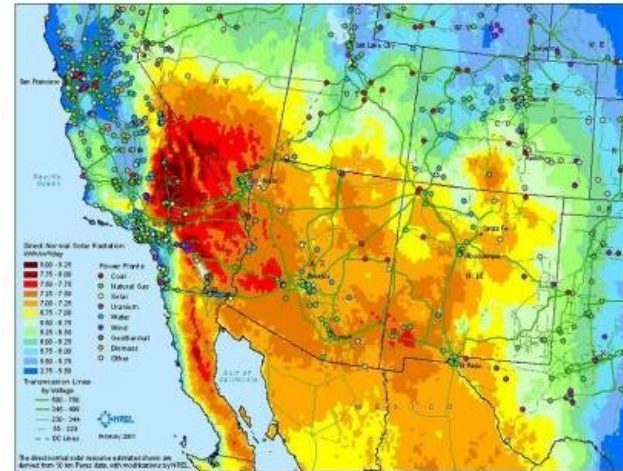
Long term: to develop high-efficiency, low-cost, high-capacity factor CSP systems.



DNI Solar Resource -- Southwest

Filters applied:

- Direct-normal solar resource.
- Sites $> 6.75 \text{ kwh/m}^2/\text{day}$.
- Exclude environmentally sensitive lands, major urban areas, etc.
- Remove land with slope $> 1\%$.
- Only contiguous areas $> 10 \text{ km}^2$



State	Land Area (mi ²)	Solar	
		Capacity (MW)	Generation Capacity GWh
AZ	19,279	2,467,663	5,836,517
CA	6,853	877,204	2,074,763
CO	2,124	271,903	643,105
NV	5,589	715,438	1,692,154
NM	15,156	1,939,970	4,588,417
TX	1,162	148,729	351,774
UT	3,564	456,147	1,078,879
Total	53,727	6,877,055	16,265,611

U.S. Capacity is 1,000GW

Annual generation of 4,000,000 GWh



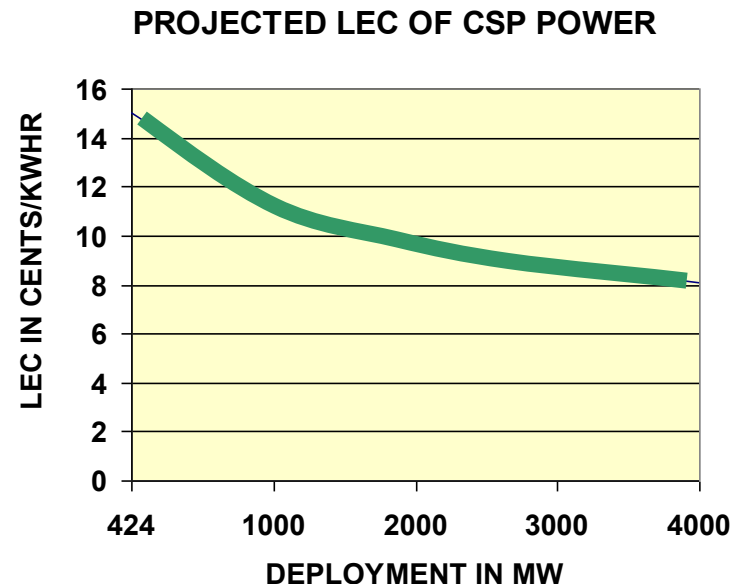
Project Costs

- Sometimes represented as \$/kW installed
- Sometimes represented as the Levelized Cost of Energy (LEC) from a plant (includes financing, O&M, profit, over the lifetime of the plant etc.)
- These are large power projects requiring 4 – 5 years to develop and deploy.
 - *Financing terms*
 - *Plant ownership*
 - *Incentives*
 - *Proximity to and capacity of substation*
 - *Ownership/cost of land*
 - *Capacity of power lines*



Cost of CSP

- Current cost of systems is \$3000 to \$4000 per kW Levelized Energy Costs (LEC) ~ 13 to 16 ¢/kWhr
- Cost Reductions are projected to reduce the LEC to 10 ¢/kWh or below with as little as 4 GW of deployment.
- Plant size and deployment (learning curve and economies of scale)
- Financing and EPC risk reduction with deployments
- R&D of new components and advanced technologies



Source: WGA Solar Task Force Summary Report



Projects in SW U. S.

PROJECT NAME	CSP TECHNOLOGY	COMPANY	CAPACITY (MW)	STATE	UTILITY
SEGS	Parabolic trough	Next ERA Energy	354	CA	SCE
Saguaro	Parabolic trough	Aciona	1	AZ	APS
Nevada Solar One	Parabolic trough	Aciona	64	NV	NV Power
Kimberlina ST Power Plant	Linear Fresnel	Ausra	5	CA	PG&E
SES Solar One – Ph 1	Dish/engine	SES	500	CA	SCE
SES Solar One – Ph 2	Dish/engine	SES	350	CA	SCE
SES Solar Two – Ph 1	Dish/engine	SES	300	CA	SDG&E
SES Solar Two – Ph 2/3	Dish/engine	SES	600	CA	SDG&E

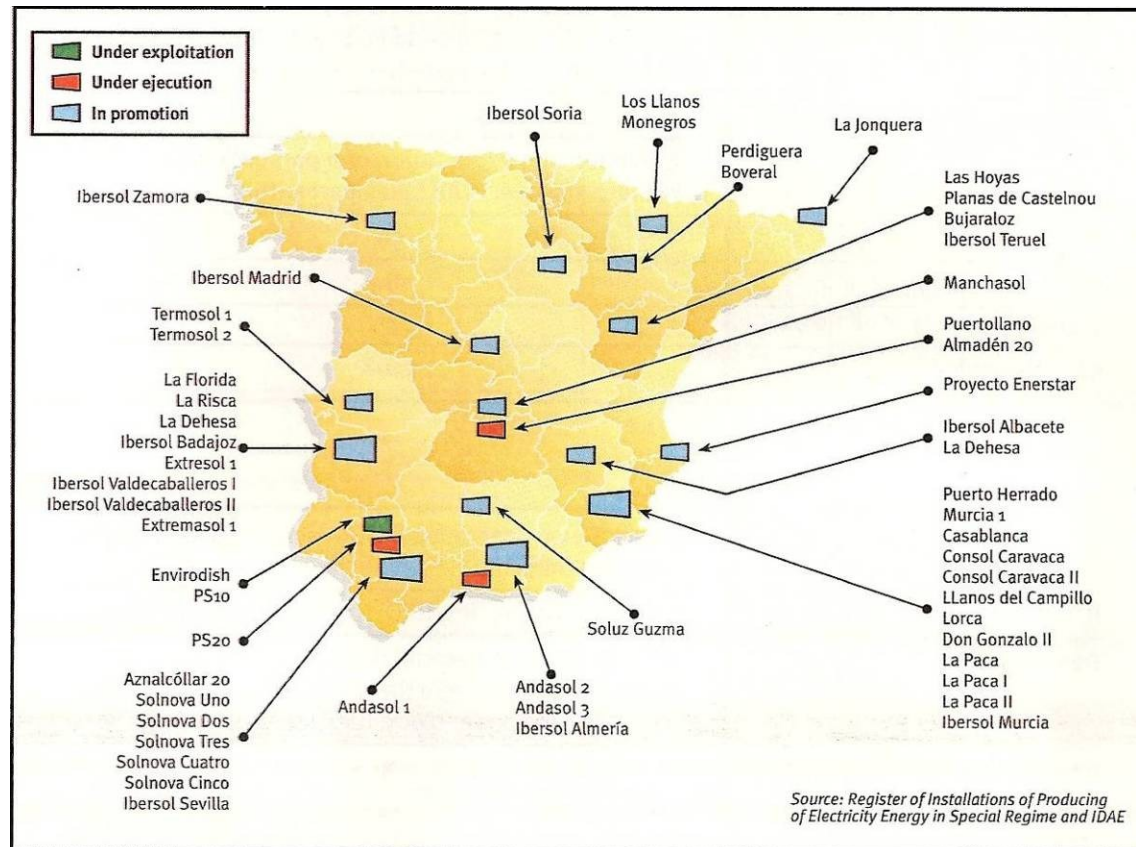
No Name	Operating projects	424 MW
Victor	Line Focus Systems	3158 MW
Mojav	Power Tower Systems	2432 MW
Carriz	Dish Systems	1777 MW
Harpe	Total	7367 MW
Palme		
Martin		
Solan		
Beaco		
Ivanp		
Ivanp		
Ivanp		
No Name		
Coalin		
No Name		
No Name		

No Name	Parabolic trough	LMC/Starwood	290	AZ	APS
No Name	Power Tower	NRG/eSolar	92	NM	EPE
No Name	Trough	Solar Millennium	242	CA	SCE
No Name	Trough	Solar Millennium	242	CA	SCE
No Name	Trough	Solar Millennium	242	CA	SCE
No Name	Dish/engine	Tessera/SES	27	TX	CPS



CSP Project in Spain

Feed-In Law incentives have created a favorable environment for the growth of CSP in Spain.



- **839 MW in construction**
- **~ 5 GW in provisional registration (40 projects)**
- **> 10 GW of Grid access applications**



The DOE Focus

- **Help industry with deployment of systems**
- **Large-scale component test and evaluation**
- **Supporting industry with R&D to reduce the cost of components and systems**
- **Evaluation of new working fluids and next-generation TES materials**
- **Development of higher efficiency, higher capacity factor CSP systems**
- **New effort to develop a DOE/Industry Solar Vision of the future**



Potential BLM Issues (1)

General Issues

- Cleared land with access for construction
- Level land required for trough and tower systems
- Dual use not likely to be an option
- Transmission access (RETI, RETA, WGA)

Materials

- Synthetic Oils (diphenyl biphenyl oxides)
- Power block lubrication oils
- Dish systems glycol in cooling system
- Maintenance shop materials
- Molten Salt: sodium- potassium-nitrates (fertilizer)
- Water treatment for the power cycle



Potential BLM Issues (2)

Water usage

- Depends on type and size of plant and location
- Trough systems ~ 850 gal/MW hr
- High-Temperature Power Tower ~ 600 gal/MW hr
- Dish Systems have captive radiators
- Mirror washing requirements ~ 10 to 30 gal/MW hr

Land Area required for plants

- Applicant ROW are “reserving” far more land than they intend to use in order to locate “best” sites.
- Area depends on type of plant, storage, and the level of allowable shading in the design of the plant.
- Area can range from about 4 to 7 acres/MW



Potential BLM Issues (3)

Visual Impact

- A 100 MW trough plant without storage will have ~ 500 acres of solar collectors w/7hours of TES ~ 900 acres of collectors.
- A power tower with storage could be as tall as 600 feet
- There will be reflections from the troughs, dishes, and heliostats with momentary glint.

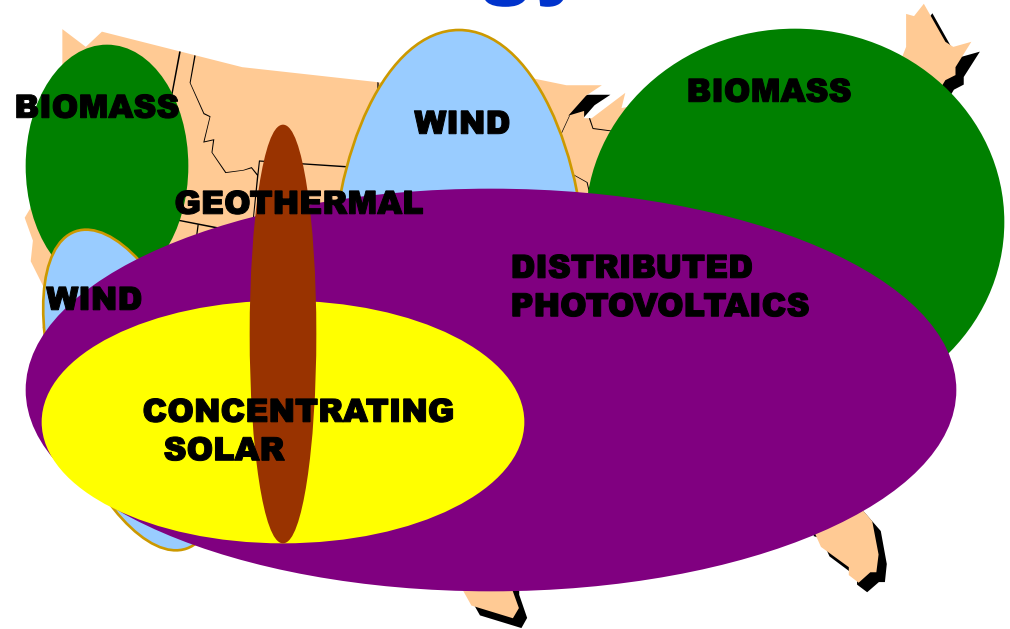


NOTE: Photographs are not comparative or representative of the technologies as they were taken at different distances from the collectors with different cameras, settings and lenses.



Why CSP and not some other renewable energy resource?

**It's not either/or,
it's that we need
them all!**



- There is no “silver bullet.” We need to develop all of our renewable energy resources to meet the challenges of the future.
- Utilize regional resources locally as much as possible.
- Establish a New National Electrical Transmission Grid that includes advanced micro-grid infrastructure and distributed generation too.